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A COMPARISON OF GLOBAL FGGE ANALYSES AND ENERGETICS (GLA VS ECMWF) FOR JANUARY 1979

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1. BACKGROUND

Several sets of Level III-b analyses from the Global Weather Experiment (FGGE) are available for use by the research community. In order to assess the impact which these data sets may have had toward enhancing our understanding and prediction of weather processes on varying space and time scales, it's essential to compare them, both globally and regionally. A detailed comparison of the global energetics for SOP-1 and SOP-2, based on ECMWF and GFDL analyses, was recently conducted by Kung and Tanaka (1983). The present study focuses on differences and similarities between ECMWF and GLA (Goddard Laboratory for Atmospheres/NASA) analyses and resultant energetics for the globe, as well as specific areas. The period of investigation is 10-27 January 1979, the early part of the first Special Observing Period (SOP-1) of FGGE. During the first two weeks of this period, both the South Pacific Convergence Zone (SPCZ) and South Atlantic Convergence Zone (SACZ) were quasi-stationary persistent features of the Southern Hemisphere circulation pattern (Huang and Vincent, 1983). Toward the end of the study period, the SPCZ decayed. The purpose of this paper is to compare the extent to which the ECMWF and GLA analyses captured the level of energy activity on a global basis and, in particular, in the vicinity of the SPCZ and SACZ. This is accomplished through a partitioning of the energy contents and conversions into zonal and eddy components.

A detailed discussion of the ECMWF data set used in this study is given by Vincent (1982) and Huang and Vincent (1985). In brief, it is a modified version of the original Level III-b analyses and consists of analyzed values of horizontal wind components and geopotential height at mandatory pressure levels from 1000 to 100 mb at increments of 5° lat/lon. Temperatures have been computed hydrostatically from the analyzed height fields and vertical p-velocities have been obtained kinematically (with an O'Brien, 1970 adjustment scheme) from the analyzed winds. The GLA data set was graciously supplied to us through the efforts of Dr. Wayman Baker and his associates at NASA-Goddard. The portion of the data used in the present study consists of objectively-analyzed values of horizontal wind components, geopotential height, temperature and vertical motions at mandatory pressure levels at increments of 4° lat/5° lon. The analyses were derived from the assimilation cycle of the GLA General Circulation Model (see Baker, 1983 for a detailed description). He also presents a sample comparison of GLA and ECMWF analyses for the North Pacific at 1200 GMT 19 January 1979.

The zonal and eddy forms of energy contents and conversions used in this study occur in two forms, space domain and wave spectrum. The space domain equations are similar to those given by Oort (1964) for the globe and Brennan and Vincent (1980) for a limited region. The spectral energy equations are the same as those given by Saltzman (1957, 1970) and only the zonal wave components for wave numbers, n=0 and n=1-15 are considered. Details regarding the application of these equations to the large-scale circulation features of the Southern Hemisphere, based on ECMWF analyses for the 10-27 January period, are given by Huang and Vincent (1985).

2. RESULTS AND DISCUSSION

As noted in the preceding section, both the SPCZ and SACZ were dominant features of the Southern Hemisphere circulation in mid-January 1979. Evidence of this is presented in Fig. 1 of the paper by Hurrell, Huang and Vincent, which appears elsewhere in this preprint volume. That figure shows outgoing longwave radiation (OLR) values averaged for the period 10-24 January 1979. Low latitude values of OLR $\leq$ 225 Wm^{-2} have been shaded since they most likely contain areas of deep convective activity a large percentage of the time (Heddinghaus and Krueger, 1981). The cloud bands associated with the SPCZ and SACZ clearly are the two dominant features in the tropics. Because of this fact, one of the main objectives of this paper is to compare the resulting analyses and energetics obtained in these two convergence zones by the two data sets of interest. The other main objective of the paper is to examine the global circulation patterns and resultant energetics, since it appears that the SPCZ and SACZ play a major role in the general circulation during the period.

Several observed and derived variables were compared at different pressure levels between the ECMWF and GLA analyses. These included horizontal wind components, temperature, geopotential height, vertical p-velocity, velocity potential, streamlines and mean sea level pressure. Most of the variables showed very good agreement for the 15 day period, 10-24 January. In particular, the global patterns of mean sea level

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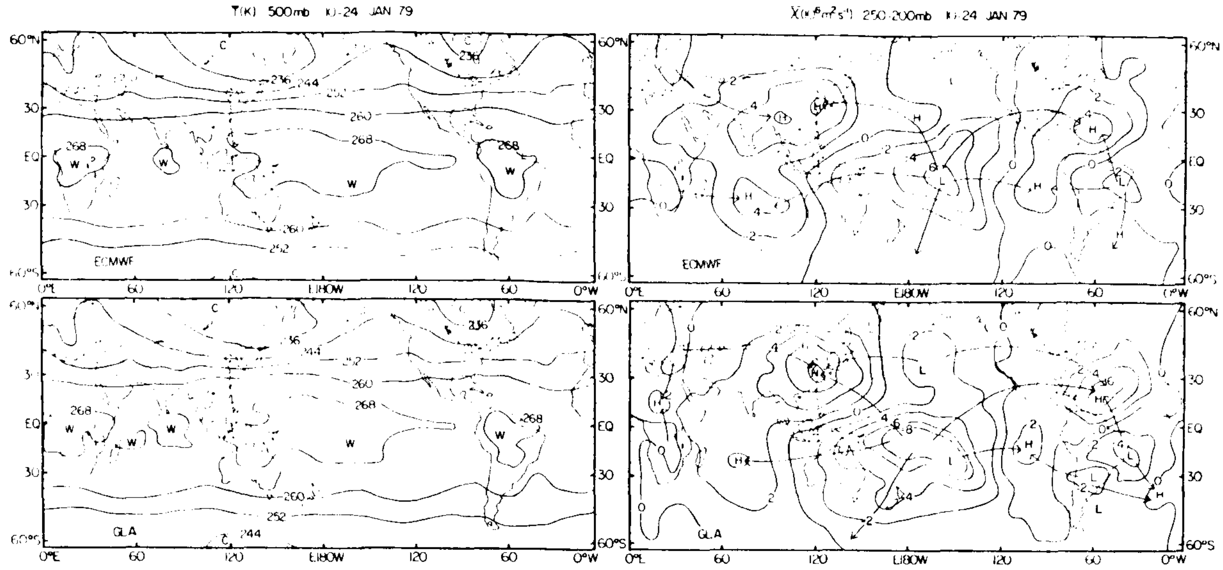

Fig. 1. Time-averaged temperature at 500 mb and velocity potential in the 250-200 mb layer for 10-24 January 1979. ECMWF (upper panels) and GLA (lower panels).

pressure, temperature and streamlines were essentially identical, both in the locations of centers of activity and in magnitude. The patterns of the remaining variables, except for vertical velocity, were nearly identical, but magnitudes (both positive and negative values) obtained from GLA analyses were frequently greater than those obtained from ECMWF analyses. Thus, there was a tendency for the GLA circulation to be more intense. The vertical velocity patterns showed the least agreement, particularly in magnitude; however, the major features of the circulation pattern were generally the same sign. Examples of two variables, temperature at 500 mb and velocity potential in the 250-200 mb layer, are shown in Fig. 1. These variables were selected for illustration for two reasons. First, the temperature represents an example of very good agreement between analyses, while the agreement between velocity potential patterns is somewhat less. Second, as will be seen later, the conversion from potential to kinetic energy is a significant one in the energy cycle, and this conversion is due to a correlation between temperature and vertical motion. Since velocity potential in the upper troposphere is an indicator of upper level divergence, it also implies the vertical velocity pattern.

Figure 1 shows a zone of high mid-tropospheric temperatures in the tropics by both analyses with maximum values over Africa, South America, Indonesia and the Central Pacific. Of particular note are the centers of warm air associated with the SPCZ and SACZ. The pattern of velocity potential shows that strong upper level divergence occurs in the vicinity of these warm core regions, suggesting that thermally-direct circulations, with warm air rising, are present in the two convergence zones. As noted above, the patterns of $\overline{\chi}$ are similar between the two analyses; however, peak values frequently are greater in the GLA analyses, which leads to stronger gradients and a more intense circulation from that data set. Also, the pattern of $\overline{\chi}$ derived from GLA is not as smooth as that derived from ECMWF. This was even more evident in the analyses of vertical motion where the GLA fields exhibited a much greater variability than those produced by ECMWF, and contained more centers of upward and downward motion, as well as greater peak magnitudes.

The remainder of the paper compares the energetics between the two analyses. Vertically-integrated energy contents and conversions, computed by the space domain technique described earlier, are shown in Fig. 2 for the globe, the Southern Hemisphere tropics, and for the SPCZ and SACZ areas. The latter two regions are centered approximately on the respective cloud bands of the SPCZ and SACZ and are located within the Southern Hemisphere tropical region. Figure 2 shows that the time-averaged global energy cycle is equally represented by either set of analyses. The main difference between the two data sets is in CE, the conversion from AE to KE, which is due to air rising in relatively warm regions and/or air sinking in relatively cold regions. As implied earlier, the GLA analyses shows a more intense vertical circulation. In the three sub-regions there is generally good agreement between the two analyses, except that GLA values for eddy contents, AE and KE, are always larger. In the Southern Hemisphere tropics and in the SPCZ area, CE is the only important energy conversion; thus, most of the remaining discussion will focus on that term.

Figure 3 shows time series of vertically-integrated values of each of the four energy conversions for the globe and of CE for the Southern Hemisphere tropics, the SPCZ area and the SACZ area. For the globe, daily values of CA and CK are in good agreement, but CE and CZ are not, although the trends of CE are similar.

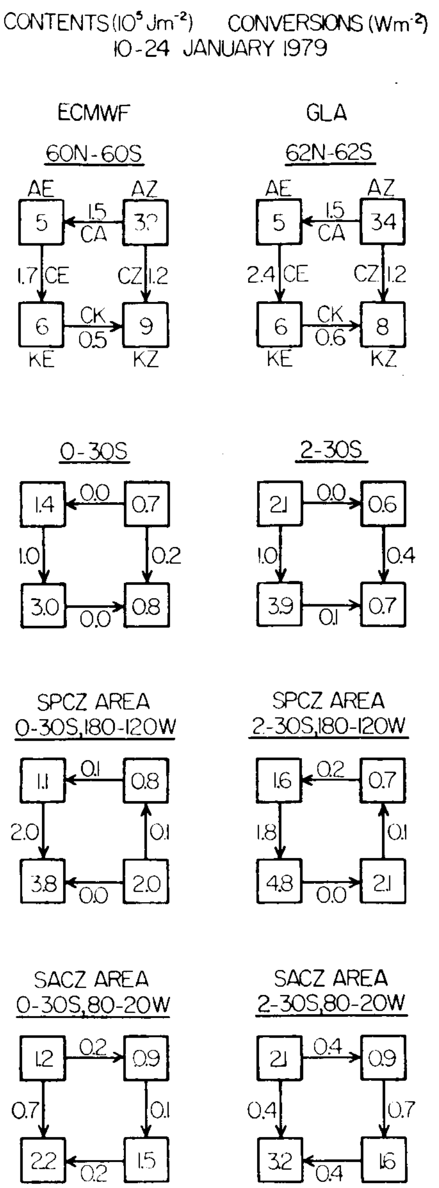

Fig. 2. Time-averaged energy contents and conversions from space domain equations for 10-24 January 1979.

Both of these conversion terms depend on the relationship between vertical motion and temperature. As suggested earlier, it seems likely that the primary reason for these differences lies in the vertical motion patterns rather than the temperature patterns.

In the three sub-areas, values of CA and CK from both data sets (not shown) followed a similar trend in time and were generally small, with GLA values being slightly greater in magnitude. Values of CZ (not shown) showed little agreement from day to day, and those from GLA exhibited considerably more day-to-day variability than those from ECMWF. However, for areas of limited areal extent, CZ generally is not a meaningful term. Values of CE in each of the three subregions show very little agreement on a daily basis (Fig. 3), even though the time-averaged

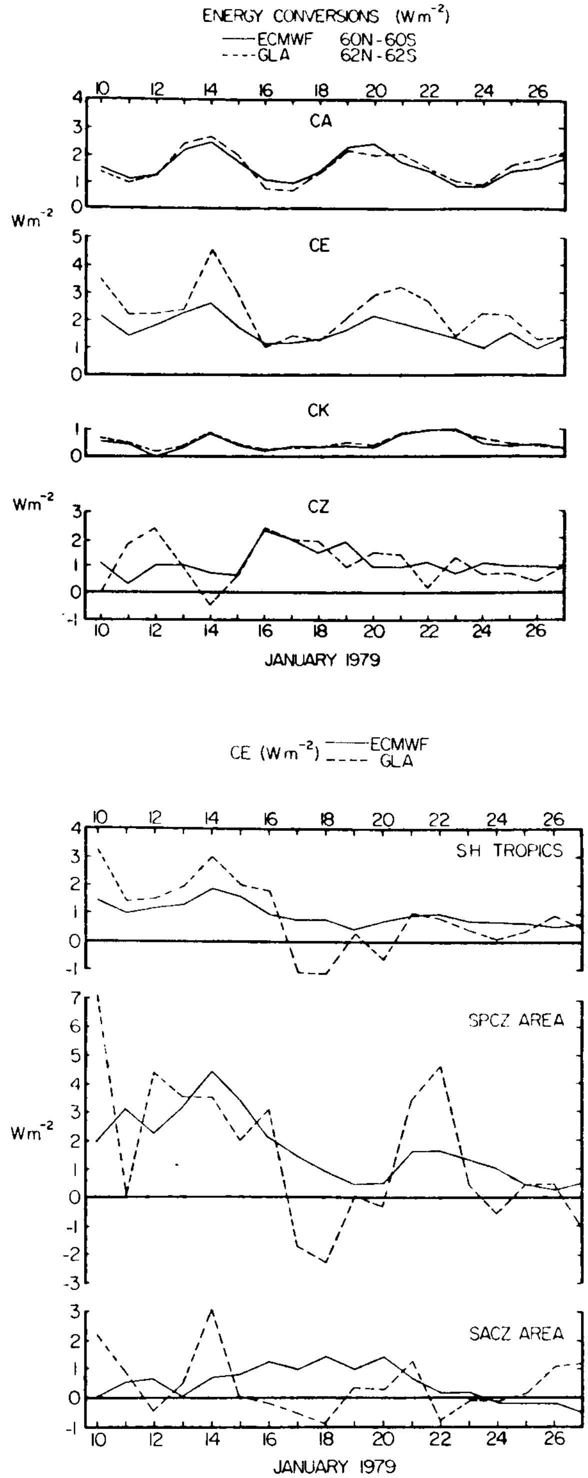

Fig. 3. Time series of energy conversions for the globe (upper panel) and for CE only for the Southern Hemisphere tropics and SPCZ and SACZ areas (lower panel).

values are similar (Fig. 2). In all regions, GLA values are more variable in time. It is important to note that the trend for the SPCZ area is the same as that for the Southern Hemisphere tropics by both analysis schemes. Thus, it appears that the SPCZ plays an important role in the intensity of the Southern Hemisphere tropical circulation. It is also seen that the greatest difference in trends between the two analyses occurs in the SACZ area. The GLA trend for the SACZ is similar to that for the SPCZ, but much weaker; whereas, the ECMWF trends in the SPCZ and SACZ are different. Hence, little can be said at this point regarding the importance of the SACZ in the Southern Hemisphere tropical belt.

In a recent study, Huang and Vincent (1985), using ECMWF analyses, found that wave number four (n=4) made a significant contribution to the CE conversion in the Southern Hemisphere tropics during the period, 10-24 January, when the SPCZ was very active. Since both analyses show a high level of energy activity in CE during that period, it seems appropriate to compare the spectral distribution of CE by each analysis. Figure 4 shows such a comparison for the Southern Hemisphere tropics. It is seen that both analyses exhibit a maximum positive value at n=4. In Huang and Vincent (1985), the four waves were aligned with the three continents and the SPCZ. As anticipated, there is more variability in the spectrum obtained from GLA data, and the GLA results show that a forced circulation occurs at medium (n=5-7) and very short (n=12-14) wavelengths. In contrast, the ECMWF values of CE are positive for all wave numbers. Finally, both analyses show that wavelengths shorter than about 4000-5000 km make only a minor contribution to the CE conversion.

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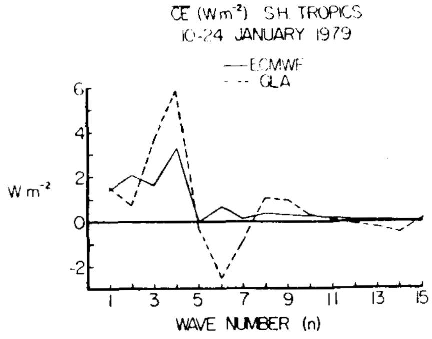

Fig. 4. Time-averaged value of CE as a function of zonal wave number for the Southern Hemisphere tropics, 10-24 January 1979.

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